

# Exposure Opportunities of Families of Farmer Pesticide Applicators

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**Background** Families of farmer pesticide applicators have unusual opportunities for exposure, directly or indirectly, to pesticides. These exposures are not well characterized.

**Methods** Subjects were 26,793 licensed private pesticide applicators enrolled in the Agricultural Health Study, a cohort study being conducted in Iowa and North Carolina. Questionnaires were completed by the applicators and their spouses.

**Results** Many indirect exposure opportunities exist; for example, 21% of homes are within 50 yards of pesticide mixing areas, 27% of applicators store pesticides in their homes, and 94% of clothing worn for pesticide work is washed in the same machine as other laundry. Direct exposure opportunities also occur; for example, 51% of wives of applicators worked in the fields in the last growing season, 40% of wives have ever mixed or applied pesticides, and over half of children aged 11 or more do farm chores.

**Discussion/Conclusions** The extent of the opportunities for exposure of family members of farmer pesticide applicators makes studies of their health important. Am J. Ind. Med. 34:581-587, 1998.

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**KEY WORDS:** agriculture; agrochemicals; pesticides; environmental exposure; occupational exposure; family

## INTRODUCTION

Farming is unlike many other occupations in that the workplace is often the same as the worker's home. Thus, families of farmers have unusual opportunities for indirect exposure to occupational hazards, regardless of whether they themselves are engaged in farming. In addition to this indirect exposure, farming is often a family enterprise; family members may assist in farm duties and, thus, have the potential for direct exposure. The fact that farming involves exposure to a wide variety of hazardous agents [Shaver and

Tong, 1991] raises concern about the extent to which family members may also be exposed to these substances.

Exposures of farm families are not well characterized; few studies have compared aspects of their exposures to those of nonfarm families. Simcox et al. [1995] measured four organophosphorus pesticides in household dust and yard soil from 26 farm homes, 22 farm worker homes, and 11 nonfarm homes in Washington; they found higher levels in the agricultural households. Loewenherz et al. [1997] measured certain organophosphate metabolites in urine of young children from 48 pesticide applicator families and 14 comparison families, also in Washington; they found higher levels in children from applicator families. In both of these studies, levels increased with residential proximity to orchards. In a pilot study, Bradman et al. [1997] measured 33 pesticides in house dust from 11 California homes; they found suggestions of higher levels for some in farm worker homes as compared to non-farm worker homes.

We examine here some indicators of potential exposure of families of licensed farmer pesticide applicators enrolled in the NIH Agricultural Health Study. We use information

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from questionnaires to characterize the potential for both direct and indirect household exposure.

## METHODS

The Agricultural Health Study is a large prospective cohort study being conducted in Iowa and North Carolina by the National Cancer Institute and the National Institute of Environmental Health Sciences. A detailed description of the study is available elsewhere [Alavanja et al., 1996]. Briefly, persons applying for pesticide applicator licenses (which must be renewed every 3 years) in these two states from 1994 through 1996 were asked to enroll in the study. Both private applicators (primarily farmers) and commercial applicators (for example, structural pest control workers) were enrolled, but only private applicators are included here. 82% of eligible private applicators enrolled in the study.

The study includes an extensive questionnaire assessment of exposures and of health. One questionnaire was administered at enrollment. Applicators were then given a supplemental questionnaire to complete and return; it included a number of items relevant to indirect household exposures. Just under half of the enrollees completed this supplemental questionnaire; those who did and did not complete it were similar in most respects [Tarone et al., 1997]. Applicators were also given a take-home questionnaire for their spouse; it included additional items on indirect exposures, as well as items relating to farm work carried out by the spouse that might lead to direct exposure. For spouses who did not return their questionnaire by mail, telephone completion was attempted. A third take-home questionnaire was to be filled out by females, either female applicators or wives of male applicators; it included information about children born since 1975.

This report is based on private applicators enrolled in the study who had either a completed supplemental applicator questionnaire or a completed spouse questionnaire or both available for use as of September 1997. There were 26,793 such applicators; 17,773 were from Iowa and 9,020 were from North Carolina. 76% had an applicator questionnaire available and 83% had a spouse questionnaire available. The additional female questionnaire was available for 70% of applicators; the responses to this questionnaire included information on 18,857 children (14,789 from Iowa and 4,068 from North Carolina).

We examined potential for direct and indirect exposure to household members. We also examined whether the potential for exposure varied with state, with characteristics of the applicators or their spouses (age, race, sex, education, marital status, presence of young children), or with characteristics of the farm (size of farm, presence of livestock, age of house). While most of these covariates had some impact, the magnitude of the variation in potential exposure was usually

**TABLE I.** Percent of Private Pesticide Applicators With Various Demographic Characteristics, 1994–96\*

	Iowa	North Carolina
Percent male	99	96
Percent married	90	85
Age of applicator (years):		
<30	6	7
30–39	25	16
40–49	28	24
50–59	22	23
60–69	15	20
70+	4	10
Farm size		
Small	1	38
Medium	37	38
Large	31	9
Very large	30	15

\*Farm size categories are defined in Methods.

small. The covariate results presented are the larger variations which were consistent across states.

Farm size categories were based on number of acres and livestock. A farm was considered very large if it had 1,000 or more acres, 10,000 or more poultry, or 1,000 or more other livestock. Large farms were those with 500 or more acres, 1,000 or more poultry, or 500 or more other livestock. Of the remainder, a farm was considered medium if it had 50 or more acres, 100 or more poultry, or 50 or more other livestock. Remaining farms were considered small.

Percentages given in Results exclude persons who did not answer the question as well as those for whom the question was not applicable. For most outcomes, up to 6% of answers may be missing; for specific pesticides, up to 14% may be missing. Because of the large sample size, virtually all differences noted were statistically significant by conventional standards ( $P < .05$ ), so no indication is given.

The Agricultural Health Study was approved by the Institutional Review Boards of the National Cancer Institute and the National Institute of Environmental Health Sciences. The study was explained to potential participants, and consent was signified by return of questionnaires.

## RESULTS

Most of the applicators in this report are male and most are married (Table I). Those from Iowa are somewhat younger than those from North Carolina. Farms in Iowa are substantially larger than farms in North Carolina.

**TABLE II.** Percent of Homes or Wells of Private Pesticide Applicators Located at Stated Distances From Pesticide Use, 1994–96

	Iowa farms				North Carolina farms			
	Small	Medium	Large	Very large	Small	Medium	Large	Very large
Distance from home to nearest area where pesticides mixed (yards)								
<50	26	24	21	19	26	15	7	9
50–100	38	43	44	40	30	32	24	23
100+	25	27	31	36	37	50	67	65
No mixing done on farm	11	6	5	6	7	3	2	4
Distance from home to nearest field or orchard where pesticides applied (yards)								
<100	49	48	52	54	39	41	50	51
100–199	25	27	26	24	20	21	20	19
200–200	6	8	8	7	8	8	7	5
300+	19	17	14	14	33	30	22	25
Distance from well to nearest area where pesticides mixed (yards)								
<50	20	20	18	17	13	13	7	9
51–100	25	30	29	25	22	23	19	19
100+	28	32	35	37	44	46	44	42
No private well for drinking water or no mixing done on farm	28	19	18	20	20	18	30	31

## Indirect Exposure

Proximity of homes and wells to areas of pesticide use was determined. Applicators reported on proximity to both mixing and application; spouses also reported proximity to application, and their information was used to indicate proximity when that from the applicator was not available. There were 21% of homes located within 50 yards (46 meters) of the nearest area where pesticides were mixed. 48% of homes were within 100 yards of the nearest field or orchard where pesticides were applied. 75% of homes had private wells as the primary source of drinking water. 16% of homes had wells located within 50 yards of the nearest area where pesticides were mixed. On small farms in North Carolina, homes and wells were more likely to be near areas of mixing but less likely to be near areas of application (Table II). These differences by farm size were less pronounced in Iowa.

Storage of pesticides in the home may lead to accidental exposure of household members. 27% of applicators reported that pesticides were ever stored (even temporarily) in their homes. In Iowa, the most common storage location, employed by 21% of applicators, was the basement. In North Carolina, where homes are less likely to have basements, the most common location was an attached outbuilding or shed, used by 10% of applicators. Storage in the home was more likely on smaller farms (Table III).

In addition to deliberate storage in the home, the potential for inadvertently bringing pesticides into the home was of interest. One indicator of potential exposure was

where applicators usually washed up or showered after mixing or applying pesticides: 79% washed in a bathroom in the home, 5% in an outside shower, and 16% in another area outside the home. A second indicator was usual laundry methods for clothes worn when mixing or applying pesticides; both spouses and applicators reported on this, and applicator information was used if that from the spouse was not available. Members of some households kept this laundry completely separate from other laundry: 2% always wore disposable clothing and 4% sent the work clothes out to be laundered or washed it in a machine used only for this purpose. The most common practice (81%) was to wash it separately in the machine used for all laundry. The remainder mixed it with the other wash, either with (3%) or without (11%) first soaking it separately. Practices varied somewhat by state and marital status (Table IV). A third indicator was habits regarding work boots; 62% of spouses reported that family members who had been working in the fields usually took their boots off before entering the house. Older applicators and those from Iowa were more likely to remove their boots before entering. In Iowa, 63% of those under age 50 and 76% of those aged 70 or more removed their boots; in North Carolina, the corresponding figures were 49 and 61%. In addition, 93% of spouses reported that there was a wipe mat by the door that was used by family members working in the fields.

## Direct Exposure

Household members besides the applicator may do farm work and thus have the opportunity for direct exposure to the

**TABLE III.** Percent of Private Pesticide Applicators Who Ever Store Pesticides in Their Homes, 1994–96

	Iowa farms				North Carolina farms			
	Small	Medium	Large	Very large	Small	Medium	Large	Very large
Any location in home	39	36	33	25	27	15	6	8
Specific locations in home <sup>a</sup>								
Home	4	3	2	2	2	2	2	1
Basement	20	23	22	17	10	4	<1	1
Garage	10	7	6	5	5	3	2	2
Attached outbuilding or shed	10	10	8	7	13	8	3	4

<sup>a</sup>Applicators may store pesticides in multiple locations.

**TABLE IV.** Percent of Households of Private Pesticide Applicators Using Stated Laundry Practices for Clothing Worn to Mix or Apply Pesticides, 1994–96

	Iowa applicators		North Carolina applicators	
	Unmarried	Married	Unmarried	Married
Used disposable clothing, sent laundry out, or washed in machine used only for this purpose	6	4	12	8
Washed separately in machine used for all laundry	78	87	61	73
Mixed with other wash	16	9	27	20

**TABLE V.** Percent of Wives of Private Pesticide Applicators Doing Stated Types of Farm Work Last Growing Season, 1994–96

	Iowa farms				North Carolina farms			
	Small	Medium	Large	Very large	Small	Medium	Large	Very large
Till the soil (plow, disk, cultivate)	23	29	32	27	16	14	9	12
Plant	28	16	14	14	55	36	24	25
Hand pick crops	26	18	17	16	54	37	25	26
Apply fertilizer, manure	9	11	10	9	27	17	12	14
Apply chemical fertilizer	10	7	7	7	26	18	8	13
Drive combines or other crop harvesters	6	14	17	16	4	5	5	6
Any of the above	43	41	44	40	66	47	37	36

various hazards associated with farming. Information on farming activities was obtained from spouses. As most applicators were males, only data from wives of applicators are presented in what follows. Regarding husbands of applicators, we note only that they were much more likely to engage in farm activities than were wives of applicators.

The extent to which spouses engaged in several specific farm activities during the last growing season was deter-

mined. In Iowa, wives were most likely to till the soil, with 29% of wives engaging in this activity. In North Carolina, planting (40%) and hand picking crops (41%) were the most common activities. Fewer wives applied fertilizer or drove combines or other crop harvesters. 45% of wives engaged in at least one of these activities. Wives on small farms, particularly in North Carolina, were more likely than wives on large farms to engage in most of these

**TABLE VI.** Percent of Wives of Private Pesticide Applicators Working Stated Number of Days in the Fields Last Growing Season, 1994–96

	Iowa	North Carolina
Never	49	49
<10 days	21	17
10–30 days	17	18
30+ days	13	16

**TABLE VII.** Percent of Wives of Private Pesticide Applicators Who Ever Mixed or Applied Pesticides, Percent Doing So for Stated Time Periods, 1994–96

	Iowa	North Carolina
Number of years		
<1	10	13
2–5	26	24
6–10	19	17
11–20	24	22
21–30	13	12
30+	9	12
Days per year		
<5	50	37
5–9	24	25
10–19	17	22
20+	10	15

activities (Table V). The number of days worked in the fields last growing season varied. Approximately half of the wives worked no days, while 14% worked more than 30 days; patterns in the two states were similar (Table VI).

Spouses of applicators may handle pesticides themselves; 40% of wives ever personally mixed or applied pesticides. Of those, 65% did both, 3% only mixed, and 31% only applied. The percentage ever mixing or applying was somewhat higher in Iowa and was highest among women with ages in the 40s and 50s, peaking in Iowa at 48% for women in their 50s and in North Carolina at 37% for women in their 40s. Among those who ever mixed or applied, 46% did so for more than 10 years and 29% did so for 10 or more days per year (Table VII). Spouses reported whether they had ever mixed or applied any of 50 specific pesticides and any of 4 classes of pesticides (insecticides, herbicides, fungicides, and fumigants). Use of 11 of the individual pesticides was reported by at least 5% of wives in one or both states (Table VIII). The most commonly used pesticides were carbaryl and glyphosate. Insecticides and herbicides were used by substantial numbers of wives, while use of fungicides and fumigants was less common.

**TABLE VIII.** Percent of Wives of Private Pesticide Applicators Ever Mixing or Applying Specific Pesticides, 1994–96\*

	Iowa	North Carolina
Individual pesticides		
Carbaryl	29.1	35.1
Glyphosate	34.8	28.6
Malathion	21.3	20.0
2,4-D	19.2	6.8
Diazinon	9.1	13.2
Trifluralin	7.7	1.0
Atrazine	6.1	2.3
Dicamba	5.9	0.8
Alachlor	5.7	2.4
Chlordane	5.3	4.2
Metalaxyl	0.5	5.1
Classes of pesticide		
Insecticides	45.3	39.6
Herbicides	41.5	30.8
Fungicides	4.3	10.9
Fumigants	2.3	5.1

\*Only those pesticides used by at least 5% of wives in at least one state are shown.

**TABLE IX.** Percent of Children of Private Pesticide Applicators Performing Many of the Activities Associated With Farming, 1994–96\*

	Iowa		North Carolina	
Age (years)	Boys	Girls	Boys	Girls
Up to 5	24	18	17	14
6–10	54	39	42	32
11–15	77	55	67	48
16+	88	55	80	55

\*Children who were reported to have never lived on a farm or who had died by the time of enrollment were excluded. In Iowa, sample size per gender-age combination ranges from 1,424 to 2,056; in North Carolina, from 345 to 506.

Information was obtained about each child born since 1975 to female applicators and wives of male applicators. Substantial numbers of children, when they lived on the farm, performed many of the activities associated with farming (Table IX). Boys were more likely to engage in these activities than were girls, and the percentage increased with the child's age at study enrollment.

## DISCUSSION

We have shown that members of households of licensed farmer pesticide applicators have several types of opportunities for indirect exposure. Many homes and wells are located

near areas of both mixing and application of pesticides. Proximity of homes to areas of pesticide use has been shown to be related to pesticide levels in household dust, yard soil, and urine of children [Loewenherz et al., 1997; Simcox et al., 1995]. Some applicators store pesticides in their homes, raising the possibility of spills and subsequent contamination of either the storage area or the path leading to it. In addition, opportunities exist for pesticides to be inadvertently carried into the home, on the applicators themselves and on their clothing. Indirect exposure to occupational agents through work clothing brought home has been shown to be important in a number of cases, resulting in both elevated exposures and disease [Knishkowsky and Baker, 1986]. Agents that have been transmitted from workers to their family members include lead, beryllium, arsenic, polycyclic compounds, chlordecone, and synthetic estrogens. Asbestos is a particularly well-known example; many cases of mesothelioma in relatives of asbestos workers have been reported.

We have also shown that spouses and children of licensed farmer applicators frequently engage in farming activities, thus potentially exposing themselves directly to pesticides and other occupational hazards. About half of the wives do some work in the fields, and 40% report having mixed or applied pesticides. In addition, over half of older girls and the vast majority of older boys participate in farm activities. The proportions of wives of applicators who participate in farm activities are generally similar to those seen in a previous survey of farm women [Engberg, 1993].

The results presented here are limited to Iowa and North Carolina. However, these two states include very different types of farms [Alavanja et al., 1996]. Farms in Iowa tend to be large farms raising grains and livestock. Farms in North Carolina are smaller and have a wider range of crops. The inclusion of diverse farm types in this study makes it likely that the results will apply elsewhere. The results are also limited to families of licensed applicators. Families of nonapplicator farm workers could have different types of exposure than do the families studied here.

Our results concern opportunities for exposure as shown by activities and behaviors of the applicators and family members. The extent of actual exposure can only be determined by direct measurement. There are plans for monitoring a sample of the families enrolled in the Agricultural Health Study [Alavanja et al., 1996]. This monitoring would include measurements of pesticide levels in both applicators and their families. Pilot studies have been undertaken [Brock et al., 1998; Melnyk et al., 1997; Shealy et al., 1997].

The consequences of exposure are uncertain but potentially serious. The hazardous exposures associated with farming are diverse, and include fertilizers, gasoline, solvents, metals, and pesticides [Shaver and Tong, 1991]. Pesticides, in particular, have been the subject of much

study; they have been associated with a variety of health effects, including neurological effects [Keifer and Mahurin, 1997], reproductive and developmental effects [Sever et al., 1997], dermatologic effects [O'Malley, 1997], cancer [Zahm et al., 1997], and other problems such as immunologic and pulmonary effects [Ecobichon, 1996; Maroni and Fait, 1993; Weisenburger, 1993].

There are indications in the literature that wives of male farmers may have health risks similar to those of farmers. A recent British study showed that the causes of death which were elevated in farmers were also generally elevated in the wives of farmers [Inskip et al., 1996]. A study from Iowa showed patterns of cancer incidence for women living on farms similar to those seen in male farmers [Folsom et al., 1996]. This similarity may be a consequence of shared lifestyle, but may also be due to shared direct and indirect exposure to farm hazards.

The fact that families of applicators have ample opportunities for both direct and indirect exposure to hazardous agents means that further study of their health is warranted. Follow-up plans for the Agricultural Health Study include both continuing contact with applicators and their families and passive follow-up through cancer registries and death certificates.

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